THE BIOLOGIST

A Quarterly Journal Promoting Research
Interest in the Biological Sciences

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1. Calls and presides at Chapter and Executive Committee meetings.
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MATING BEHAVIOR DIFFERENCES IN ANIMALS AS AN ISOLATING MECHANISM

David Miller

INTRODUCTION

Isolation between closely related sympatric species of animals can be achieved by several means. In the first place there can be a sufficient difference in the ecological preferences and/or daily habits of the species so that they do not come into contact with each other, and thus have no opportunity for interspecific matings; in this case one could argue that they are not truly sympatric. The first line of defense against interspecific mating by species which do come into normal contact is simple refusal to attempt such matings. This would seem to be the most efficient isolating mechanism possible for such species because it prevents wastage of energy and of gametes, but it presents certain problems to the animals involved. They must be able to distinguish members of their own species from others sufficiently well so that they are stimulated to mating activity only by intraspecific individuals. This report deals with some of the observational and experimental papers which have been written on mating behavior and on the presence and efficiency of the stimulation and recognition mechanisms involved.

The total literature on mating behavior and ethological isolation is very great, so it was thought most efficient to limit this review to a consideration of some of the work on three groups of animals: spiders, for which Kaston's paper of 1936 is discussed; Drosophila, for which six papers are discussed, the most important being Spieth's 1952 paper; and fish, for which the paper of Haskins and Haskins in 1949 on three species of Poeciliid fish is discussed.

SEXUAL ISOLATION IN SPIDERS

Kaston, in 1936, published his observations on the mating behavior of 24 species of vagabond spiders (i.e. non web spinning species). The courtship patterns are quite variable from species to species, though within the same family there is strong similarity in general pattern. Kaston unfortunately makes little effort to abstract the basic pattern for each genus or family studied, so that the reader is left nearly entirely on his own in trying to grasp the general picture. Usually the female must accept the male before copulation can begin, and she is stimulated to do so by the courting behavior of the male.

In general the courtship patterns for the families studied may be summarized as follows.

Lycosidae

The male must first come into contact with the female — he will not court if he only sees her. On contact he begins to posture with his body and moves and postures his forelegs and palps in front of the female. The markings as well as the movements of the forelegs and palps are distinctive for each species. When the female is receptive she lowers the front of her body and allows the male to mount over her head. The actions of the female are inadequately described by Kaston, but in two of the species studied he states that the female spars with the male with her forelegs immediately before allowing him to mount.

Kaston did several experiments with the males of this family to determine the stimuli which cause them to court. He found that the male is generally stimulated by the sight of any Lycosid female, and will attempt to touch her. If she is of the wrong species he apparently discovers this upon contact and runs away. By experimenting with a leg removed from a female and held in a pair of forceps, and with a chemical extract obtained by washing the leg in ether and allowing the ether to evaporate on a glass slide, he found that in some species the simultaneous perception of tactile stimuli from the washed leg and the chemical stimulus from the extract would elicit courtship without the male having to see a female, while in other species sight alone was enough to elicit courtship.

Pisauridae

Only *Dolomedes scriptus* Hentz was studied in this family, and it fits the general Lycosid pattern described above except that the chemical stimulus from the extract of the female leg was alone enough to elicit courtship, no visual or tactile stimuli being required. The female acceptance was not described except to say that she allows the courting and may indulge in leg play with the male. In other species of this family earlier observers had reported that the male gives the female a fly as a part of the courting routine, but Kaston found that he did not need to supply flies to this species. He does not state whether they were used in courting if they were supplied, but implies that they were not.

Attidae

Kaston's experiments indicate that the male is stimulated to court purely by the sight of the female. He will court females of other Attid species, but when he approaches quite close to a foreign female he turns and runs away without having to touch her. The courtship patterns are quite similar to the two families discussed above, but in addition the male toward the close of courtship strokes the female with his front legs. If she is receptive her acceptance is described as permitting the stroking and subsequent mating, but if she is not receptive she merely runs away.

Thomisidae

These spiders apparently have much poorer sight than those above, and thus their courtship is not dependent on visual elements. Contact is accidental (if there is no contact the two sexes seem oblivious to each other) and immediately upon contact the male is likely to seize, stroke, or tap the female, depending upon the species. In three of the four species studied the male ties the female down with silk before mating with her, but this probably is not to force her cooperation. The female is able to free herself from the bonds after mating, and probably could do so before mating if she were not receptive. It seems probable to me that if the female is not receptive the male will not get far enough along in his courtship to tie her down.

This paper was one of the earliest of the modern approaches to the study of mating behavior, and as such has been a model in the field for some time. It would profit greatly, however, by an analysis of the behavior patterns involved in relation to evolution and isolating mechanisms. At the time it was written it represented a purely descriptive and analytical report on the senses involved.

Kaston has concentrated on finding the stimulus that causes the male to court, and thus he leaves the reactions of the females pretty much alone except for partially describing some of the more visible ones. In the evolutionary sense, however, the important mating is one which does not merely begin, but one which ends in the successful production of viable offspring. For this reason a thorough understanding of any mating behavior must include a study of the methods of acceptance and refusal of the female, and of the sensory stimuli which cause the female to accept or reject the male.

As he is not dealing with mating behavior as an evolutionary phenomenon, Kaston does not attempt to derive an ancestral type of behavior for each group studied, to trace the evolution of this behavior in various species, or to explain how such evolution of the behavior pattern is possible. This is not a criticism, because Kaston does not set out to do this or make any pretext of doing it — I merely present it as an avenue for further investigation. Certainly a good deal of Kaston's data could be used toward this end.

SEXUAL ISOLATION IN DROSOPHILA

With the increased use of Drosopila for genetic study there has also been an increase in the study of over-all Drosophila biology, including a good many papers on the mating behavior. I here review six of the papers in this field.

Work by Spieth and others previous to the papers I have chosen had given a general outline of the behavior of members of the genus in general, and of the particular patterns found in several species.

(1) The male approaches the female and taps her with his front legs.
(2) In most species he circles to her rear and postures, meanwhile vibrating one or both wings in a manner characteristic of the species and licking her genital plates with his proboscis.
(3) Receptive females usually spread the vaginal plates and in many species also lift or spread the wings.
(4) The male then inserts his proboscis in the exposed area between the vaginal plates before mounting the female.

Spieth in 1949 presented a study of interspecific mating behavior between six species of the *willistoni*-group. In some interspecific crosses the male tapped the female (Step 1) and the courting then stopped. Spieth says this indicates that the male is able to discriminate foreign females by tapping and that this behavior shows that discrimination in these matings is entirely a function of the male, since normally (i.e. in intraspecific matings) the female gives no response at this stage. In other interspecific crosses the males posture and vibrate the wings, and the females refuse them (Drosophila females have several standard refusal devices), so Spieth says that in these cases discrimination is a function of the female. If one considers that the movements made by Drosophila flies in their courtship are often small and very difficult to observe, caution in interpretation is called for. The only proof that the female normally gives no reaction to tapping is that no such reaction has ever been seen. This does not seem to me strong enough evidence to state that the male must be the discriminating partner if courtship stops at tapping. Spieth's opinion here may very likely be correct, but the point can not be considered completely proven. On the other hand it seems nearly indisputable that, if the female gives a positive refusal after the male has postured and vibrated his wings, it is she who is discriminating.

In crosses between *capricorni* males and *willistoni* females the males were often repelled before they had tapped. This may indicate that the *capricorni* males can tell *willistoni* females from their own either by sight or smell.

Spieth found that when a male tapping a foreign female accidentally touched her with his antennae he stopped tapping immediately. Thus it seems that species discrimination can be at least partly a function of the antennae. Mayr in 1950 presented the results of experiments in which he placed *pseudoobscura* males with *persimilis* and *pseudoobscura* females and found that the "isolation index" was .975 (1.00 represents complete isolation). When the females had their antennae removed the over-all mating activity dropped and the isolation index fell to .125, which is nearly no discrimination at all. Thus it seems that here discrimination is a function of the female, and antennae again are important in it. Mayr says that some other stimuli in addition to antennal ones must be received by the females, since there was still mating activity when the female antennae were removed. He quotes a suggestion of Spieth's that some of the stimulation may be scent and that the male fanning of the wings may be to blow the scent toward the female. This work would be supplemented by making the reciprocal cross, i.e. by trying *persimilis* males in the same experiment.

Merrell in 1949 presented evidence from crosses between two strains of *D. melanogaster* that the duration of courtship is a function of the female while the duration of the mating is a function of the male. This means that the male courts until the female repulses or accepts him, and discrimination thus seems to be the function of the female. However since other work has shown discrimination in some interspecific crosses to be a function of the male, Merrell's work would seem to apply only to the species on which it was done, *melanogaster*.

Miller in 1950 published the results of crossing *affinis* and *algonquin*. He found in these species a high percentage of male-male courtings, and an even higher percentage of them in interspecific matings. In other words, these males prefer to court males of their own species rather than females of the other species! He too takes up the idea of chemical stimulus for species discrimination, the chemical evidently being at least similar for different sexes of the same species. (It is interesting to note that Miller reports no tapping in these species, although Spieth in 1952 states that tapping occurs in all species including these.)

Undoubtedly the most important work in the field of *Drosophila* mating behavior is that of Spieth published in 1952. In this lengthy paper (74 pages) he discusses the mating behavior of 101 species and subspecies of *Drosophila* (as well as three species in related genera) and attempts to tie together the work that had been done to that time. He presents a description of the behavior of each species and subspecies studied, and also gives a summary for each species group and subgenus at the end of that group. On the basis of the similarities in behavior he attempts to show the relationships within the genus and the probable paths of evolution of the mating behavior. Preliminary to this he attempts to reconstruct the mating behavior of the ancestral Drosophila, from the elements common to many species, especially distantly related ones.

Spieth's paper also presents a rather thorough analysis of what is known about the stimuli involved in courtship. In most species the visual stimulus of seeing another walking *Drosophila* of either sex is enough to cause the male to investigate; or the observing male may be walking instead of the observed fly. The mosaic vision of an insect compound eye would give much the same stimulus no matter which individual was moving, the observer or the observed. In two species, *subobscura* and *auraria*, mating never occurs in the dark, from which it may probably be concluded that the males must see the females to court. In other species, likewise, darkness decreases mating.

The investigation which follows sighting another individual consists in all species of tapping, though in some species tapping may be dispensed with after the first time by a given male — i.e. after his threshold of excitability has been lowered by contact with females of his own species. Apparently in various species tapping serves: (1) to enable the males to distinguish sexes, though in most cases tapped males counter-signal to the tappers thus giving another method of distinguishing; (2) to enable males to distinguish females of their species from others; (3) to stimulate the males to further courting; (4) to stimulate the females, because tapped females sometimes give the acceptance response with no further courting on the part of the male. The nature of the stimulus, other than tactile, resulting from the tapping is unknown, but it may be chemical, at least as received by the male, and received by the front tarsi.

The next action of the male, posturing, with its various elements which may include stroking the female, licking her genital plates, and wing vibration, probably presents to the female a complex of stimuli the summation of which stimulates her to give the acceptance response, because removal of various individual receptors, as for example the antennae mentioned above, will lessen but not eliminate mating. Probably the exact stimulus responsible for species discrimination by the female at this point varies from species to species, or again the whole stimulus complex may be responsible. Spieth states that repeatedly females of the *virilis* group which were near a mating pair gave the acceptance response every time the male vibrated his wings, even though they themselves were not being courted. Spieth suggests that this may be due to auditory stimuli from the wing vibration.

The acceptance reaction of the female probably results in a chemical stimulus for the male, because in many cases the male must lick the area exposed between the spread vaginal plates before he will mount the female. In those species where this does not take place the chemical released by the reaction is probably strong enough to be olifactorally stimulating.

The two principal sub-genera, Drosophila and Sophophora, have specialized in entirely different stimuli. Sophophora has specialized in distance stimuli, according to Spieth, since the tapping and licking actions are either quite brief or may even be omitted, while the wing vibration is almost universally present in the subgenus. The males apparently are able to receive the acceptance stimulus from the female without having to lick the exposed area between the vaginal plates.

The sub-genus Drosophila, by contrast, seems to be dependent largely on contact stimuli. Tapping of the females, as well as rubbing or scratching them with the front legs during posturing, is widespread, and the licking of the genitalia is often prolonged and vigorous. The males apparently have to lick the area between the spread vaginal plates to get the acceptance stimulus.

Spieth found that the presence of females of their own species causes the lowering of the sexual threshold of the males so that they become visibly excited, court frequently, and even tap other males more frequently than otherwise. Bastock in 1956 wrote on the threshold of excitation of normal *D. melanogaster* and its yellow mutant. She found that the yellow males spend less time in wing vibration and genital licking and more time in posturing, which resulted in reduced success in mating with normal females. She explained the male actions on the basis of their state of excitement, saying that posturing represented a low state of excitement, wing vibration a higher one, and licking a still higher one. Thus if the normal excitement state is cyclic, and if the yellow mutants have a lower mean state of excitement, the behavior pattern is explained.

Since the difference between these strains of *melanogaster* is similar to differences found in other organisms between species, Bastock states that sexual isolation could begin in just such a manner, perhaps as the pleiotropic effect of an adaptive gene. If yellow were adaptive, for example, and it is adaptive under certain conditions, the mating behavior of some populations might shift along with a shift to yellow and this difference might eventually become greater due to later divergence in the two stocks. However, such a suggestion seems unfounded on the basis of her study, simply because the effect of yellow on the females was not studied. In order to achieve isolation between two sympatric forms, there would have to be a discrimination of yellow for yellow as well as normal for normal. Normal females discriminate for normal males, but what if yellow females also discriminate for normal males and not for yellow ones? If this is the case the net effect is a selection pressure against yellow which would tend to eliminate it from the population, or, if the selection by other means for yellow was strong, to establish a polytypic population without divergence.

The mating behavior of Drosophila has been studied extensively, but certainly a vast amount is still unknown. The actual stimuli involved in the various steps are in nearly all cases imperfectly known or only inferred, and this is where there is most urgent need for work. Experiments on a few species similar to the ones performed by Kaston on his spiders but dealing with the stimuli for all stages of the mating behavior and with both sexes would go a long way toward clearing up the problem.

SEXUAL ISOLATION IN POECILIID FISHES

Haskins and Haskins in 1949 reported the results of a study on three species of fishes, all of which are sympatric and very similar, *Lebistes reticulatus*, *Poecilia vivaparia*, and *Micropoecilia parae*. Females of all three species were placed together with Lebistes males and "gonapodial contacts" counted immediately after adding the males and after one week. The data showed that when first placed together the Lebistes males made more contacts with Micropoecilia females than with their own species! However, after a week of association with mixed females, the discrimination was almost perfect (over 90%). Thus the ability to distinguish must be learned. The fish initially were taken from mass cultures of their own species.

The males of these species are distinctively colored, while the females are drab and very similar. Since the females appear to be entirely passive in the mating act the authors assume that the coloration of the males is a warning for other males, not a device to stimulate the females or allow them to discriminate, and that discrimination between species is a function of the males.

Admittedly this work is purely preliminary, and the authors stated in 1949 that further experiments were in progress. I have seen no later papers by them, however. There are certain fundamental problems suggested by these experiments. In the first place, as the authors themselves admit, there is no certainty that "gonapodial contacts" always represent sperm transfer. The evidence of observation seems to indicate that they do. However, it is possible that there is discrimination during the mating act, and thus that sperm do not get transferred during interspecific matings nearly so often as the data would indicate. Second, there must be some way that the male can tell during mating that he is mating with a female of the wrong species, if he is to learn to discriminate his own females. Then if he can tell during mating, this bears strongly on the problem mentioned above on completed matings. Third, if there is discrimination during mating then this as well as the subsequent learning could as easily be a function of the female as of the male. Whichever sex is the discriminator, it must receive at least two stimuli, one in the learning phase only which tells it it is performing an interspecific mating and one before matings in both phases, probably visual, which allows it to tell the species apart once it has learned.

Learning as a part of mating behavior in vertebrates is known in other groups as in birds. In his book *Systematics and the Origin of Species* Ernst Mayr states that the song patterns of birds, which play a part in the mating behavior, are probably not inherited by the young but are learned from their fathers. In some cases birds raised with other species have prefered to mate with the other species. However this is not the whole story, because cowbirds and cukoos, nest-parasites of other birds, still manage to mate within their own species, as do species in which the young are raised entirely by the female and thus never have a chance to contact and learn from their fathers. Such abilities are, of course, an evolutionary prerequisite to the development of the sort of habits that such birds possess.

DISCUSSION

Mayr, in *Systematics and the Origin of Species*, says: "Recent studies by the students of animal behavior, as well as the revised interpretation of many earlier observations, indicate that behavior differences are among animals the most important factor in restricting random mating between closely related forms." It certainly seems from the groups that have been studied that this is true in cases where the species are "truly sympatric" and thus have opportunity to mate. Under the experimental condition herein discussed the isolation was nearly complete regardless of the mode of discrimination, and it is probably even more complete in nature.

Selection would tend to favor the formation of sexual isolation. If two species diverge and then become sympatric — I agree with the opinion that sympatric speciation is rare if not impossible — those members of either species which mate within the species thus use all of their gametes to carry on the species line. By contrast, those which mate interspecifically would be using some of their gametes at least in the production of hybrids, which usually are less viable or less fertile than the pure species. Thus selection on a percentage basis would tend to eliminate individuals prone to interspecific matings and favor the strengthening of the sexual isolation. If there were internal sterility barriers the evolution of sexual isolation would be even faster, since in this case an individual which mated interspecifically would leave none of his gametes from that mating for a further generation.

As a sidelight, a consideration of some of the cases where hibridization between normally separated species has occurred in disturbed habitats might show that these are species which have no ethological isolation and are in nature normally kept apart by ecological preferences. Thus disturbing the habitat has brought together species not normally in contact which while isolated have been unable to evolve strong enough differences in mating behavior to keep them apart.

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David Miller is an active member of Psi Chapter, University of Washington.

CAREERS IN BIOLOGY: CONSERVATION OF NATURAL RESOURCES

It is becoming increasingly necessary for the American people to become more conservation-minded in the handling of their natural resources. In this necessity lie the many career opportunities for the general conservationist.

General conservation treats of the interrelations among the many resources and the actions involved in combined resource management. For example, water use often can't be handled independently by the specialists in engineering, soil erosion, agriculture, fisheries, and municipal and industrial needs, but must be seen as a total problem. The wise use of resources is not only a technical matter, but depends also on private and public policy. It thus gets involved with the economic, social and political aspects of resource development. For these reasons, a curriculum in Conservation is a broad, liberal education with concentration, but not over-emphasis, on natural sciences and natural resource studies.

Students in Conservation should understand that it is not a technical field that will necessarily lead directly to professional status and employment as a conservationist. It does, however, provide for entrance into many fields, and because it aims at a sound general education, it is a basis for many opportunities.

Training in Conservation helps to meet the increasing demand by state, federal and international agencies, by educational institutions, and by business organizations for men and women with sufficient breadth of training and understanding to see the conservation picture in its entirety and work with professional people having more specialized training. Also, the schools, colleges, and universities are more and more looking for teachers who can present the subject of conservation in a comprehensive way, often as a part of other subjects. Many of the job opportunities for conservationists lie in the field of education. Concisely, conservation provides an excellent basic education for any college student no matter what he may later specialize in or do for a living.

MAN'S PLACE IN NATURE*

Melville H. Hatch

The purpose of the present paper is to attempt to exhibit the texture of events that is man and his affairs in its setting of a constantly changing universe. It is presented because the evolutionary picture that is unfolded and that is largely the result of the scientific investigations of the past century is part and parcel of man's position midway through the twentieth century — a picture that challenges man's whole previous philosophical outlook on himself and his nature.

From the vantage point of the mid-twentieth century, the ultimate pattern of nature that science reports is a vast system of millions of galaxies of stars and gas with a thinly distributed intergalactic gas, mostly of hydrogen atoms, in between. Moreover, these galaxies seem to be retreating from each other at a rate that is proportional to their distance from one another, so that, at a distance of about two thousand million light years and a lapse of time of some ten or twelve thousand million years, they would retreat from each other at greater than the speed of light and accordingly become unobservable to each other, and so would pass out of each other's "observable universe."

When we seek for the origin of such a system of expanding galaxies, we are met by a pair of alternatives. Fred Hoyle suggests the possibility of a static expanding universe by supposing that, as the galaxies separate, new hydrogen atoms come into existence, which are then incorporated by gravitational action into the pre-existing galaxies or, in regions of space where pre-existing galaxies are too widely separated, aggregate to form new galaxies. Our own galaxy appears to be four or five billion years old. The universe is thus pictured as without beginning or without end: a vast system of galaxies forever expanding away into infinity!

More conventional is the view of George Gamow, which derives all the galaxies from a fantastically dense hot unstable mass of undifferentiated matter-energy, which is called "ylem," a mass which was, perhaps, only thirty times as large as the sun, and came into being four or five thousand million years ago. Immediately this mass of ylem is supposed to have started to expand. Within five minutes protons, electrons, and neutrons had formed. Within half an hour the nuclei of the chemical elements had arisen. After some thirty million years, under the influence of gravitational attraction, the primordial ylem had broken into galaxy-sized masses which began to separate and within which, still as a result of gravitation, stars and planets began to form.

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*For over fifteen years the author of this paper has been associated at the University of Washington with an interdepartmental general education course for seniors entitled "The Analysis of the Modern Cultural Crisis." In this course professors from various departments point out the bearing of their subjects on an understanding of the situation in which mankind in general and western man in particular finds himself. The present essay is the author's attempt to throw the light of evolutionary science on this problem. In the course itself it is entitled "The Natural History of the Crisis." Huxley's famous title has been adopted here as more suitable in the present setting.

Gamow is silent on the origin of this improbable aggregation of primordial ylem. Perhaps we are in the presence of an Uncaused Causer, the modern cosmological equivalent of Aristotle's Unmoved Mover, and the universe is a one-act play, with the galaxies in the process of mutual retreat into infinite space. Or perhaps the cosmological process is an unending one, as suggested by Hoyle, and the Uncaused Causer is constantly bringing new hydrogen atoms into existence. Or again, perhaps there is something the matter with the conclusion that the galaxies are in mutual retreat, and the universe is really a static finite system capable of alternate senescence and rejuvinescence — but astronomers at present seem to give a nearly unanimous "no" to such a possibility.

Hoyle speculates that initially a galaxy is composed exclusively of hydrogen atoms. Numbers of these eventually condense under their mutual gravitational attraction to form "first generation" stars. Under the enormous pressures and temperatures that build up in the interiors of these stars processes occur which are essentially similar to what happens in the hydrogen bomb and heavier atoms are built up with the release of radiant energy. Hoyle believes that it is possible to show that in some of these "first generation" stars of the proper magnitude even the heaviest atoms are formed, that eventually some of these stars blow up in vast stellar explosions, scattering their accumulation of heavier atoms about the galaxy, and that it is out of this new mixture of atoms, still predominantly hydrogen, that "second generation" stars like our Sun are formed. Again, these new stars start to radiate energy, but when they are of the proper average small size, again like our Sun, this radiation of energy goes on at a nearly constant rate and may continue for as much as ten thousand million years or longer. Eventually, however, the hydrogen fuel would seem to become exhausted and the star explodes and/or collapses to form a dense dwarf star which would appear, after a very long period, to become cold.

Meanwhile, out of the mixed heavy and lighter atoms surrounding such a star, a planetary system would seem sometimes to form. Most of the lighter atoms escape into space, leaving the heavier atoms to form a planet like the earth, in which the proportion of heavy atoms is very much greater than in the sun.

Some twenty-five hundred or three thousand million years ago or more the young earth was devoid of living things. The continental masses of lighter rocks floated in isostatic equilibrium in a base of heavier materials, providing the continents and seas and mountains of the geologist. The same sorts and relative amounts of atoms with the same potentialities existed then as now. But the world was biologically sterile.

The type of system that was ushered in with the origin of living things provides a clue to the whole matter we are investigating. It was an improbable event, this origin of the first living things, that was permitted but not compelled by the environment; and its precise nature the advance of our science is permitting us to understand with increasing clarity.

Living matter is a very complex organization of one to multiple million-atom molecules with the property of extracting materials and energy from its environment by means of which it lays down exact reduplications of itself. If one envisages a million-atom molecule producing a replica of itself exact in every detail of the precise relation of every one of its million atoms to every other one of them, he has some inkling of the altogether amazing and unlikely thing that the living system is.

Now it seems probable that the first living thing arose by the coming together of atoms in the initial environment into such a pattern that it started producing replicas of itself! If we ask why the sterile culture medium does not spontaneously swarm with living things, the answer is that the proper combination of atoms is so improbable that within the time and space limits of the culture medium it is quite unlikely to occur. It is so unlikely, in fact, that if such an event were ever reported by a laboratory worker, it would be put down to prevarication on his part, to contamination from some outside source, or to some other sort of error.

Throughout the present essay I shall be emphasizing the inconstant dynamic aspects of these aggregates of million-atom molecules we call living things. In thus stressing the living creature's tendency to change, we should not, however, lose sight of the fact that, in contrast with the inorganic world out of which they emerged, they were extremely stable systems. The organism's power to maintain a certain internal stability and to transmit that stability or certain aspects of it through many thousands or millions of generations of its descendants is one of its most important characteristics. This must not be forgotten throughout the stress on change in the balance of the discussion.

I direct your attention, accordingly, to the property of dynamic instability of these aggregates of million-atom molecules, their constantly changing equilibrium, because upon that hinges the entire plot of our story. Living things, as living things, are always and inevitably engaged in this matter of reduplicating themselves, more commonly termed "growth and reproduction." Change, as Herakleitos observed and as the second law of thermodynamics reaffirms, is the order of the day throughout the entire realm of nature, but the instabilities of living systems are not entirely continuous with those of inorganic nature. The instabilities of organisms are primarily concerned with enzyme-produced chemical changes, and as such are many times as intense as are the chemical changes taking place in the immediate inorganic environment of living things.

The first living things, like all their successors ever since, were constantly taking energy and materials from their environment and producing exact replicas of themselves. But the environment in which these first organisms found themselves — the amount of material capable of conversion into living material — was limited and the capabilities of their geometrical ratio of increase was very great, so that eventually the environment became filled and only so much new living matter was produced as was concurrently destroyed.[1] Thus there came into existence with the first living things a struggle for existence.

I now wish to consider the factors making for diversity among living things, since the reduplicating ability already referred to would make for numerous individuals, but always of the same kind.

A lesser factor making for a multiplicity of living types from the very beginning is the circumstance that all living things as we now know them have the habit of transforming materials from a condition in which they can use them to one in which they are of no further use to that particular kind of organism. The outstanding example is the green plant that with the help of the radiant energy of sunlight transforms carbon dioxide back to organic carbon compounds and molecular oxygen as rapidly as animals change the organic carbon compounds and oxygen into carbon dioxide. Similarly, as present, it requires six or seven or more different kinds of bacteria to keep the nitrogen of the world in circulation. It would appear then that from the very beginning or from almost the very beginning a primary condition for the existence of life on the planet was a diversity of nutritional types.

The original earth was by definition sterile. The appearance of living things was probably preceded by the appearance of numerous types of non-living (i.e., non-self-reduplicating) molecules only less complex than the first living molecules or aggregates of molecules themselves, and it has been widely suggested[2] that the first living things ate these complex non-living molecules. Their capacity for reproduction, however, must have meant that the supply of complex molecules soon became exhausted, whereupon the first organisms were under the necessity of changing their food requirements or perishing. Several times — perhaps many times — living things may have thus arisen and died out; but eventually the proper sequence of mutations in the chemical structure of the first organisms occurred and a mutually self-sufficient society of organisms arose. If the appearance of a single type of living thing was improbable enough, how much more improbable was the development of several types of living things interadapted so as to keep the materials of the environment in proper circulation!

The consideration of the major factor making for a multiplicity of living things takes us back to one of their most basic properties, namely the ability of these aggregates of million-atom molecules to reduplicate themselves exactly. A moment's reflection will show that the wonder is not that living things vary, but that they are as constant as they are. In other words, variation or mutation is due to the occasional failure of these million-atom molecules to reduplicate themselves precisely. It is known, of course, that certain types of radiant energy enhance the likelihood that exact reduplication will not occur. But there does not seem to be enough radiant energy in the environment of organisms to account for the mutation that is known to occur, so that reliance would seem to have to be had on the more general factor just referred to.

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[1] *Paramoecium*, a one-celled animal, with the capacity of dividing fifty times a month could convert all available materials into living matter in about sixty days. Actually, however, the rate would be much slower because of their slow rate of locomotion. If a paramoecium can swim one millimeter in one minute, it would take on the order of 40,000 years for one to swim half way around the earth!

[2] Oparin, *Origin of Life*, 1928; Howowitz, National Academy of Science, proceedings, 31, 1945, pp. 153-157.

Now most mutations are probably lethal to the organism in which they occur. Most of the rest are in varying degree unfavorable and are eliminated by natural selection. A few only are favorable to the organism and permitted to survive. The result is, however, that under the pressure of the geometrical ratio of increase and struggle for existence these few favorable mutations tend to be preserved and evolution is the result. It can thus be seen that a tendency toward evolution was implicit and consequent upon the properties of the first organisms. But only evolution in general was implicit in this way.

In this way there developed a nearly unique property of living things. One of the most pervasive principles at work in the physical world is the second law of thermodynamics, which describes the irreversible tendency of energy to degredate to lower and lower levels and eventually to disperse as heat. This is the famous running down of the universe. Without in the least going against this unversal principle, living matter has, as it were, added a biological dimension to nature. As a result of heredity, mutation and a tendency to overpopulation and its consequent natural selection, living matter has, with the passage of geological time, become not simpler but more complicated. At each instant in the life of each organism energy — solar energy in this case — is being degraded, but the long time result has been a series of increasing levels of biological complexity, culminating in the appearance of man.

Almost concomitant with the appearance of living matter itself was the appearance of sex. Sex involves the fusion of two cells in the process of reproduction. It makes it possible for mutations that originally arose by chance in distinct lines of descent to be united in the same line. Moreover, it results in a constant mixing and reassortment of mutations already present, presenting various combinations to the environment for acceptance or rejection, and has been of the greatest importance in promoting evolutionary change. It is nearly universal among living things.

The precise course that evolution took was determined by two factors: the organism itself and the environment. Both are complex and variable. That the organism will vary is apparently assured by its nature, but what mutations will occur, that is to say, in what exact ways the aggregates of million-atom molecules will fail to reduplicate themselves precisely, is within more or less extended limits a matter of "chance." By this one means that mutations are the result of factors operating at the molecular-super-molecular level in the organism's reproductive processes which are not directly connected with the environmental factors to which the organism is subject. In addition, every time a mutation becomes established, the organism possessing it comes to have a capacity for further mutation that is somewhat different than it had before.

Moreover, the environment varies as well as does the organism. There are first the long, slow geological changes to which our planet is subject. On the other hand, there are the changes in the biological environment of the organism. Every time a new type of organism comes into existence as the result of favorable mutation, previously existing types are likely to have to readjust to the change that has thus been produced in their environment. Thus the whole community of organisms and ultimately the whole world community of organisms has the same sort of dynamic instability that characterizes the individual organism. And my object in the present paper is to present for consideration some of the unstable biological systems that lead up to the present crisis in human affairs.

The nature of the earlier biological systems is almost exclusively speculative. The rocks furnish a record of only the hard parts of organisms, and organisms with extensive hard parts were a relatively late evolutionary development. Entirely conjectural, then, must be the earlier systems or communities of micro-organisms competing with each other, varying, succeeding, failing in the struggle for life.

Moreover, we must suppose that then as now the biological world was not homogeneous throughout. Differences in physical conditions, in depth, in light, in ocean currents, in temperature, would favor certain organisms in certain places, others in others. Thus there developed not so much a single unstable system, but a system of unstable systems in varying degrees of independence of one another.

In a short view the life of any single epoch would have appeared a stable permanent self-perpetuating thing, but comparative examination at intervals of a million, ten million, or a hundred million years would have revealed the instabilities to which reference has been made. Eventually we have to suppose that larger many-celled organisms arose, that animals developed bilateral symmetry and nervous systems the more effectively to hunt down their plant and animal food, and the blood and respiratory and excretory and skeletal systems that made possible the more massive bodies that natural selection favored. If we could reconstruct the whole story in detail, we should have numerous unstable systems to pass in review to cover this portion of our chronicle.

It was probably during the Silurian period, about 345 million years ago,

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[3] The age of rocks in years is ascertained by a chemical analysis of their contained radio-active materials and decomposition products. Knowing the rate at which radio-active atoms decompose, the age of the rocks can then be determined.

that living things first began to crawl out upon the land. First the vascular plants made the land habitable for animals. The first land animals, from this same period, were scorpions, probably accompanied by other types of terrestrial arthropods (segmented animals with segmented appendages) not so far discovered by the geologist. Thirty-five million years later, in the Devonian, spiders and mites and salamanders, the latter derived from fish ancestors, had appeared on the scene, and by another hundred and seventy-five million years, in the Pennsylvanian, the winged insects and the reptiles were in evidence.

Terrestrial organisms from the first had had to meet a fourfold challenge from the environment. One, the lack of a supporting medium they met by a skeleton. Two, the presence of gaseous oxygen they met by tracheae or lungs for inducing this oxygen into solution before passing it on into the body fluids. Three, the scarcity of water they met by a protective cuticle, and four, they protected their germ cells from evaporation by establishing fertilization within the body of the female and the deposition around the fertilized egg of a protective shell.

Mammals arose from reptiles, differing from them most significantly in the possession of warm-bloodedness, enabling them to remain active at a temperature at which a cold-blooded animal is lethargic. The mammal's hair is an insulating system in connection with the maintenance of body warmth. The long retention of the embryo in the mother's body is the extension of this same warmth to the developmental stages. The first mammals are known from the upper Triassic, 175 million years ago, not half-way through the Age of Reptiles, but for 100 million years they remained small, none being larger than a small dog.

The modern world began to develop with the Cretaceous period, 135 million years ago. The continents were in something like their present position. The flowering plants were coming in: with protected seeds suited for ready dispersion by wind or animals, with flowers mutually stimulating to plant and insect evolution, with the capacity of giving up their ancestral woody stems repeatedly to become herbs and especially to become grasses. The factors involved in the extermination of most of the reptiles at the end of the Cretaceous, 75 million years ago, are still largely unknown, but they were followed by the rise of the mammals.

By the Eocene, 58 million years ago, a group of arboreal mammals known as Primates had developed. They were provided with hand-like appendages and binocular vision for making their way through the trees. In common with other lines of mammalian descent, the size and quality of the brains of these ancestral monkeys increased as the generations passed. Somewhere along the way they took to producing only a single young at a birth, which meant that slowness rather than speed of development could be favored by natural selection. Such a tendency is impossible where multiple births are the habit, since under these conditions the most rapidly growing embryo is favored.

In the course of twenty million years, by early Oligocene, the Primates improved their social organization. No longer as an inchoate chattering mob did they range the forest ways, but in small orderly family groups each led by a single male. By another fifteen million years, which is to say by lower Miocene, certain of these monkeys had lost their tails and were beginning to acquire still larger brains and the larger body size of the great apes.

And then, somewhere between one and ten million years ago, some of these great apes came down out of the trees. Perhaps somewhere a forest was drying up. Or perhaps their bodies were becoming too bulky. At any rate, as the immediate human ancestor came out of the trees a number of things happened. The primary adaptation may well have been a modification of the pelvis for erect posture.[4] This would have released the hands from their previous locomotor function and would have made them available for doing things with. And then, the brain responded to the opportunity for manipulation! The erect posture, of course, likewise affected the foot, which is one of the most characteristic and profoundly modified of human structures.

Man's ancestors had entered the world with a definite neurological pattern by means of which they had reacted to the stimuli of their environment in more or less narrowly restricted ways. Changes in this pattern were effected only as the result of mutation in the underlying genes preserved by natural selection. As a consequence of this process, after 2500 million years and as the result of the rise and fall of innumerable changing systems, an organism of the complexity of a great ape had come into the world.

It is impossible to reconstruct what the precise sequence of events may have been. Greater brain capacity, greater manipulative skill, articulate speech, more complex social organization, more adequate conceptual thought — all may have developed together in complex interrelationship. The most remarkable circumstance of man's rise is, of course, precisely this system of conceptual thought. Man's developing brain in constant interaction with his developing speech gave rise to an interrelated system of memories which resulted in its possessor coming to recognize himself as an integrated personality persistent in time. Anticipation of future events arose; thinking, logic, reason, a recognition of good and evil all came into being.

The consequences were momentous! Random events could be seized upon and incorporated into the behavior. Trial and error was born. A new mechanism of change had appeared. We speak of it as social inheritance, and it came to be able to produce changes very much more rapidly than had the method of gene inheritance. By its operation the random occurrences that came to be incorporated in the behavior pattern of the individual were transferred by means of articulate speech to other individuals of the social group. Thus language, customs, techniques, beliefs, traditions, ethical concepts, etc., came to be the possession of the group, and as each group, generation after generation, came to have slightly different experiences, so the social inheritance of each group came to be slightly different.

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[4] I owe this suggestion to Dr. Ernst Mayr of the Museum of Comparative Zoology at Harvard University.

At first, perhaps, the prehumans or humans employing learning may have used it over only a trifling portion of the entire field. On the other hand, I can well conceive it being urged that a system of memories may be an all or none matter. Either the organism lacked it and operated on the basis of inherited behavior or it had it and the inherited behavior pattern was cast out in favor of learning. Even the most halting system of social inheritance must have introduced instabilities and have effected changes at many times the rate that could prevail under the most rapid sort of germ cell mutation and heredity.

It remains now to depict some of man's discoveries that have time after time injected new and more new instabilities into the system of biological systems that has been human life on the planet for the last hundred thousand or more years. For man, once he acquired conceptual thought and the power to learn and to teach his fellows, was sitting on a veritable volcano. Most of the time, of course, he was following faithfully and safely in the ways of his fathers. And most of his innovations were harmless little things of little consequence, forgotten as rapidly as found, or incorporated in group tradition with little effect. One is reminded of the normal course of germ cell inheritance in the generality of organisms. But — and here is where the volcano lay — there was never any knowing when something important would turn up!

Up to ten or fifteen thousand years ago the sequence of discoveries is conjectural, but the significance of those discoveries is crystal clear. Tools enabled man to expand his dietary from plants and insects and perhaps shell-fish to fish and birds and mammals and made a larger population possible. Clothing and fire made it possible for him to occupy areas previously uninhabitable because of inclement climate. Tribal organization involving a regulation of the sexual desires resulted in a more complex social life, more effective hunting parties, more effective competition with other groups. Religion and his discovery of God and his own immortal soul gave man the fortitude to meet the vicissitudes and accidents of life with courage and with strength. Such were the revolutions of man's first several hundred thousand years. Such were the techniques that enabled a larger number of semiindependent primitive cultures to spread over the six continents to the number of about ten million persons.

Some ten thousand years ago the processes of cultural change began to accelerate. The initial discoveries were innocent enough to superficial view, namely, that plants and animals could be cultivated and reared under human control. But the consequences were momentous, and the neolithic arts of agriculture and animal husbandry spread rapidly in the Old World. Settled life on a larger scale became possible. On the one hand, this made for a division of labor and a quickened mental life, which is to say, a further acceleration of the process of discovery in the more populous neolithic villages, so that eventually men learned how to work copper and bronze and, long after the neolithic way of life had been supplanted by civilization — iron and steel. On the other hand, it made possible the accumulation of wealth basically in the form of stores of food. It developed that in the cooperative groups that were set up certain men gained the ascendancy: Serfdom, slavery, injustice for the many, prerogatives and leisure for the few appeared.

The neolithic order proved particularly unstable and transitory. According to Arnold Toynbee, in no less than six localities in the course of the next few thousand years neolithic man made the transition to Civilization. Babylonia, Egypt, Crete, India, China, and Central America were the places where this occurred. The "neolithic cooperatives," if one may coin such a term, were potent with possibilities, and needed only the appropriate challenge to bring forth that super cooperative which is civilization. Toynbee surmises that it may have been the great reed-beds in the river valleys of Babylonia, Egypt, India, and China, the arid conditions of Crete, and the tropical jungle of Central America that provided the challenges that set in motion the rapid changes, which is to say the peculiar instabilities, of the several civilizations involved. Writing was invented, which further accelerated the process of social inheritance.

Spengler and Toynbee have suggested the cyclic nature of the civilizations so far to have developed.[5] The sources of the instability reside primarily in an inadequate cooperativeness between the human individuals that make up a civilization. For, great as is the complexity of the human organism, potent as are learning and social inheritance in bringing about an ever increasing adaptation to the environment, and intricate as are the interrelationships involved in a civilization, these factors have so far proven incapable of producing a stable society, a society capable of expanding with man's increased control over his environment without exhibiting those weaknesses and schisms and internal conflicts that eventually cause its downfall.

A civilization arises and grows in the presence of proper rapport between the leaders and the led. The original form of political organization in a civilization is the city state, and with the passage of time the economic relationships of the several city states become closer and

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[5] As the reader of this section on "The Natural History of the Crisis" and the "Introduction" will have seen, I have been profoundly impressed by the Spengler-Toynbee cyclical interpretation of history, regarding it as one of the most important discoveries of the present century. The student should be warned, however, that many historians and anthropologists find the Spengler-Toynbee interpretation unacceptable. It is important in understanding the cyclical interpretation of history to realize that the repetitions indicated involve a much less rigorous order of inevitability than do the repetitions in a physical system like the solar system. The systems involved are organic with an inherent capacity to change, and new factors like more adequate ideas of religion, social justice, science, and representative democracy keep appearing. Moreover certain secular phenomena like the gradual spread of civilization over the earth and certain aspects of technological progress do not conform very well to a cyclical pattern. On the other hand, the course of Western civilization since 700 or 800 A.D. can be described and understood as resulting in the present crisis without reference to the cyclical theory.

and closer. Eventually, in the course of a dozen or so generations, the bonds of sympathy between leaders and the led begin to break down. The leadership tends to concentrate on its own immediate ends, and spiritual stasis ensues. The overt evidence of this comes in the leaders' inability to establish political harmony with the leaders of the neighboring political entities. Wars break out. At first it is the smaller powers at the center of the civilization that are in the ascendancy and between which the contests for power occur. The central powers, however, exhaust themselves in mutual strife, and the field is left to the larger peripheral states. Eventually, by a quasi-physical law, one power gains the day and establishes a peace of exhaustion — a civilization-wide empire.

A civilization has other expressions, however, besides the purely political one. With the development of writing and the close and long association of humans together in cities, the mechanisms of social inheritance become still further improved. Accompanying and/or following the initial political failure of the central polities to integrate adequately and as though to compensate for the lack of continued growth at the political level, art and philosophy develop and the civilization becomes involved in a process of cultural maturation. Following to its logical extreme the division of labor which characterizes every civilization, tradition is challenged and overthrown and society tends to develop into "splinter" groups. The diversity which Thucydides represents Pericles as rightly praising as one of the fairest results of the democratic way of life has its dark side as well. With it men tend to lose their common religious, moral, and aesthetic values, and it is possible that such factors, independently of the political factors previously referred to, if allowed to work to their completion, would eventually bring about the spiritual bankruptcy of a civilization.

So far in human history, however, the political factors have been paramount. Before the above mentioned processes of cultural maturation can make their effects felt, the schism between the leaders and the led begins to tell decisively. These periods of cultural decadence become times of soul-searching analysis. The leaders, deprived of even nominal political activity by the creeping autocracy, seek salvation in philosophies of detachment: Buddhism in early India, Epicureanism and Stoicism in the Hellenic world. At the same time the masses seek refuge from the injustice of their rulers in great ethnic religions. Thus the principle of the universal brotherhood of man was formulated during such periods of cultural decadence: by Ikhnaton (1375 B.C.) in the time of Egyptiac decadence, by Amos (760 B.C.) in the time of Syriac decadence, and again by Jesus (30 A.D.) in the time of Hellenic decadence. It has remained for our own scientific age to establish a scientific basis for the brotherhood of man by showing that all races of men are virually — not exactly, but virtually — equal in mental endowment.

At long last, however, frequently in response to external forces, the civilization falls in social confusion. The aristocrats pass, but the masses and their religion serve as the basis for a new integration and a new civilization at a future period. In fact Toynbee has recently suggested that one of the most significant results of the rise and fall of a second generation civilization may be the appearance of a "higher" religion. By this is meant a religion that transfers its worship from the processes of nature or from man's own corporate self (i.e., society) to a transcendent God in whose love and worship man realizes his full nature. Toynbee intimates that the development of such a higher religion in accord with the findings of science and philosophy as well as with the ethical and spiritual needs of man, is an important element in the resolution of the crisis that we face.

Toynbee describes with variations the rise and decadence of about twenty-one civilizations, and thus he finds our Western civilization to be a second generation lineal descendant of the Minoan civilization that arose in Crete out of Neolithic antecedents. Between us and the Minoans is the Hellenic civilization, save only our own the best understood and best documented. It arose before 1100 B.C. as a vast system of city states distributed from Asia Minor to Sicily. But, as always, leadership failed, indicated decisively by the Greeks' failure under the great — but not sufficiently great — Pericles to convert the Delian Confederacy into a democratic state. For a hundred years the central powers contended with each other: Athens, Sparta, Argos, Corinth, Thebes, Syracuse. Then the peripheral powers moved in. The Macedonians and Alexander could conquer the Near East as far as the borders of India. Like so many since, however, they could win the war but not the peace. Alexander's generals and their heirs fought each other for nearly a hundred and fifty years, eventually falling victim to another and greater peripheral power, Rome, that held the Greek world in subjection for over five hundred years.

When Hellenic civilization died it left behind a social inheritance of moment. Immediately there was the Christian religion — a religion of love and kindness and cooperation. Though its ideals are rarely realized, they tend constantly to point the way to better things. And its practical influence is revealed by the fact that Western civilization dates its chronological era from the birth of Christianity's founder, 700 years before it began. The other heritage from the Greeks was philosophy and science, which did not, however, become a possession of the West in an important way until the period 1200 to 1600.

The history of Western civilization repeats with variations that of the civilizations before. It arose as a system of city states extending from northern Italy to the Low Countries and its initial failure was the inability of the Italian cities of the fifteenth century to organize an adequate stable democratic polity. Culturally the West bloomed in the Renaissance just as had Greece in the Age of Pericles, and just as with Greece political ascendancy eventually passed to the peripheral powers of Macedon and Rome, so with the West political ascendancy passed to the peripheral powers of Spain, France, England, Prussia and Austria. The expansion of Western Europe into the New World suggests the spread of Greek culture to the borders of India in the time of Alexander;

and Napoleon's transitory power represents a preliminary imperialization of the West suggestive of Alexander's empire in the Greek world. But among the nation states that succeeded Napoleon representative democracy appeared, something that did not happen in the post-Alexandrian kingdoms and confederations in Greece. But the essence of the history is the same. The nation states have exhibited the same inability to integrate — to keep the peace — as did the city states before them. At first ascendancy rested with the new second order central powers — England, France, Germany, Austria — but these polities have exhausted themselves in inconclusive struggle, and the contest is now between the great new peripheral powers, the United States and Russia. In terms of ancient politics, the time is now late third century B.C. when Rome and Carthage and Macedon were girding for the final struggle.

A few paragraphs back was mentioned the acquisition by the west of Greek philosophy and science between 1200 and 1600. The attainments of Greek philosophy and science were magnificent but limited. Without printing, without an extensive use of the experimental method or the inductive logic, with interest in speculation tending to be paramount over observation, it never became a potent agency of social change.

But what had been relatively unimportant in the possessions of the Greeks and of their first successors, the Arabs, became socially dynamic in the hands of the Westerners. First there was printing, an element of incalculable importance in promoting social inheritance. Then the Western world was a society of free artisans intent on discovering better ways of doing things. Finally, science itself developed important new techniques.

First among these techniques was the inductive logic of Galileo (d. 1642) and Francis Bacon (d.1626), making for the more adequate and never ceasing collection of new facts. Then there was the critical philosophy of Galileo, Hume (1739), and Kant (1781), stripping away from scientific procedure false questions of ultimate "why's" and "wherefore's," of final ends and inner essences. Science was left free to study the only thing it could, the apparent interrelationships of phenomena. Thirdly, there was the trial-and-error experimental method of Galileo. Only by controlled experiment has it proven possible to disentangle the interrelationships of phenomena and subject nature to human will.

At first development was slow. One hundred fifty years elapsed between the mechanics of Galileo and the dawn of chemistry under Lavoisier (1794); but by the nineteenth century, concomitant with the rise of the nation states, science reached maturity.

On the one hand, descriptive science revealed man's place in nature and made necessary the recognition of the mythological elements in religion. Laplace's nebular hypothesis of the origin of the solar system (1796), Copernicus' heliocentric solar system (1543), Lyell's uniformitarian hypothesis of the developing earth (1830), Darwin's organic evolution (1859), and, in our own century, the Spengler-Toynbee hypothesis of historical cycles and astrophysics and galactic and metagalactic astronomy are a few of the outstanding achievements of descriptive science that are giving man an opportunity to assess his cosmic position. If man is ever to escape the squirrel cage of unending cycles, he must first determine the nature and structure of his trap!

On the other hand, experimental science gave to western man increasing control over nature, until by the middle of the nineteenth century it became apparent that a modicum of leisure for all and slavery and/or exploitation for none were possible in an adequately ordered society. Agriculture, medicine, steam, steel, electricity, plastics, and, now, atomic energy are only the principal rubrics under which man's mastery of nature may be mentioned.

At long last we have come to the "crisis of our age" — the struggle between the second order peripheral powers of the United States and Russia at either extremity of the Western world, in possession of instruments of destruction without previous parallel in human history. Even without ideological reinforcement, the competition of the United States and Russia is such that historical precedent suggests that on the grounds of purely nationalistic politics they would now enter upon a conflict for dominion over the West. But to the issue of conflicting nationalisms have been added ideological differences that make a peaceful outcome very difficult if not unlikely. Both the United States and Russia prides itself that its polity is the last word in adequate democratic political organization and that its philosophy gives it the key to understanding and dominating nature. Each regards its rival as representing irresponsible tyranny and the victim of a philosophy of illusion and self-deception. Each has glaring flaws in its own social structure, but each distracts attention from its own faults by a never ending insistence on the defects of its rival.

The problem that men face today is similar to that faced ever since civilizations first arose in Sumeria, in Egypt, and in the Indus Valley; and in particular it is the same that they faced in Greece and in renaissance Italy. Political integration of the Western World, perhaps of the entire world, in a single political organization of some sort seems inevitable. And the political problem is one of how men are to integrate their socieities without loss of their basic rights and without the rise of fatal schisms in the body politic.

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CAREERS IN BIOLOGY: FISHERIES

All waters of the world, fresh and marine alike, will be harvested more intensively in the future, for food as well as for fun. Job opportunities for qualified fishery workers are therefore greatly on the increase.

Fishery specialists may find employment in State and Federal Agencies such as Conservation Departments, the U. S. Fish and Wildlife Service and the pollution control units of the U. S. Public Health Service. For those interested in world experience there are fishery jobs in the Food and Agriculture Organization of the United Nations as well as in the State Department agencies dealing with technical assistance to foreign countries. Here, as in other fields, natural talent in writing and public speaking, re-inforced with pertinent training may lead to employment in the area of adult education and public relations. Some openings also exist in the teaching profession.

The great fisheries of the world are roughly divisible into two kinds —sport (recreational) and commercial (supplying food for man and his animals and raw materials for industry). Work in both of these areas rests upon knowledge of the properties and ways of life of aquatic organisms. It is also dependent on an understanding of the physical, chemical, biological and socio-economic factors which influence the quality, abundance, and utilization of the resource. Thus a student of fisheries most often majors in science but is encouraged to attain cultural breadth in his training, particularly in his undergraduate work. Later he can enter specialized graduate study, oftentimes along with part-time professional employment.

CAREER OPPORTUNITIES IN BIOLOGY: FORESTRY

Forestry is the profession devoted to management of timberlands—growing, harvesting, and marketing wood—and to the conservation of wildlife, water, and soil resources.

Foresters appraise the value of lands and of the timber growing upon them and apply practical economics to the buying and selling of forest products. They plant trees, thin and prune young forests, mark trees for cutting, and protect forests from fire, diseases and insects so that continuous production of timber may be assured. They foster and make available to the public the recreational values inherent in wild lands. Harvesting forest products means building roads, logging timber, and transporting the products from woods to mill. Some foresters work in the forest, others in administrative jobs, and still others in research.

Some foresters work for public agencies, such as state forestry departments and the U.S. Forest Service. Other opportunities are available in service agencies such as research and extension departments of both Federal and state governments, and in the U.S. Bureau of Plant Industry, Bureau of Entomology and Plant Quarantine, and the Soil Conservation Service.

Foresters also are employed in private industry, mostly by paper, lumber, and public utility companies, for whom they manage lands, buy and sell lands, timber and products, or fill administrative posts. Trade associations also employ foresters, while others are self-employed in the management of their own lands or in serving as consultants for other timberland owners.

Because the forester must perform many different functions, his education must also be broad. In addition to technical competence, he must speak and write well and he needs the background of a general education.

WIT'S END, A PRIVATE LABORATORY FOR BIOLOGICAL RESEARCH

Vance Tartar

Since 1950 my biological studies have been pursued in a little lab which I built myself, far away on the shores of the Pacific Ocean. Because of the uniqueness of this situation I have been asked to describe an arrangement which runs counter to recent tendencies in institutionalization and group research.

Although I would like to be able to claim that my lab is the result of critical analysis and bold decision, the truth is that like almost all of us I suffered many a dislocation during the war years which brought me to my wit's end. I finally found myself separated from any academic institution whatever. I labored for two years in local fish and oyster businesses. How was I to start research again?

A new and radical beginning would be possible if the actual work and yield were of the essence, regardless of the absence of all the usual signs and trappings of institutionalized research. Fortunately, my own personal need of independence had led me to choose problems and an organism, and to discover an approach, which made the minimum demands for equipment and space. This was the grafting of ciliate protozoa and in particular of the very elegant and amenable Stentor. My micromanipulator was the human hand, stentors could be found anywhere and grown without much room in peanut-butter jars, and the only expensive equipment needed was a good microscope.

I bought the dissecting scope in two installments. Limited means proved an advantage. I omitted buying the sub-stage stand and bored a hole in the bench to let light through from a source below. But this is the best arrangement for microsurgery since the microscope rests low and is easy to bend over, and one has the whole forward half of the bench for arm rest and stabilization out to the elbows. Addition of a second-hand piano stool and a spring switch which turns on the microscope lamp automatically when one leans forward over the scope completed the essential means. Since the light also turns off when one is recording observations, the bulbs have twice the usual life and the animals are protected against excessive illumination and heating.

Thus assured that I could do grafting experiments on the morphogenesis of Stentor at home, I proposed this project to the American Cancer Society and asked for the minimum I could live on for a year. I shall always be grateful to this Society and its panelists for taking a chance on me. It was also necessary in order to abide by the charter of the Society that I associate myself with an institution so I turned to my alma mater, the University of Washington, to whom I am also indebted

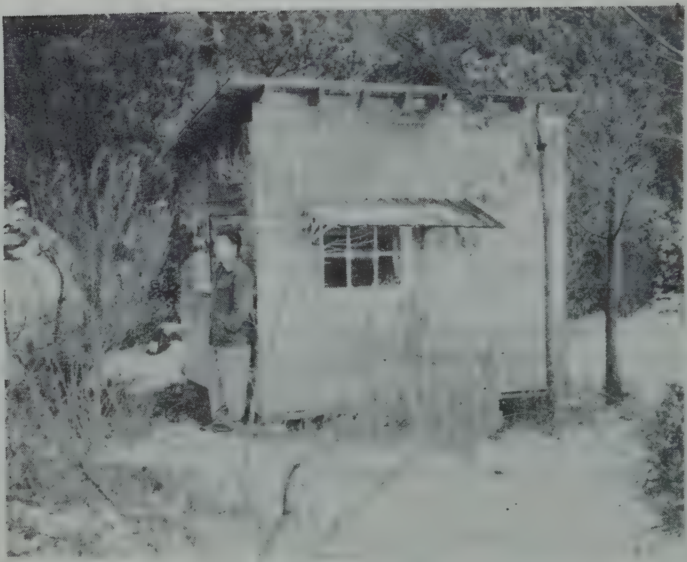

Fig. 1. The home laboratory, with author, near Oysterville, Washington.

for the faith shown by the Department of Zoology in agreeing to sponsor an unusual arrangement. Several years later when I spoke at a symposium of the Society for the Study of Development and Growth an older member of the granting panel told me that they had been pleased that I had asked for only what I really needed.

While awaiting a verdict on my application I built my own home and provided laboratory space within it. Though I could scarcely pound one nail straight when I began, my father-in-law, who is an admirable pioneer type, taught me the age-old lore of studs and joists, and the house soon rose among the ferns and pine trees on a sand ridge between the Ocean and Schoalwater Bay. Soon after the first child arrived, it became obvious that an infant crying for its bottle is no asset to research, and though winter was coming on, I stopped research for two weeks to build a separate lab away from the house.

This building is 8 by 10 feet and stands today as I made it then, adequate to my needs. Well insulated and heated by a glass-electric panel on a thermostat, the lab also serves as an incubator for the protozoan cultures; for the temperature is never allowed to drop below 60°. Glass needles are drawn out with a handy-man's alcohol torch since there is no source of gas. A bench for operating and shelves for cultures and equipment — mostly from the ten-cent store — complete the setup. On the sunny side a slit-like window admits no damaging amount of solar radiation on the animals. The *Stentor polymorphus* Müller with its photosynthetic chlorellae are kept near the west window, still away from direct sunlight. At this window, which looks out over a marsh, I sit in my captain's chair every morning before breakfast, cogitating on biological and other problems, far from the distractions of metropolitan life — even as I am writing this now. One autumn morning a black bear loped by on his way to the woods north of here. Deer often come to graze on the marsh before dawn, and a lone coyote a few weeks ago came forward to sniff toward the lab but soon retired into the willows. A ditch in the swamp proved a good source of several kinds of Stentor. Over by the bay a new species of this genus was discovered which has not yet been found elsewhere.

There is something humanely satisfying about such a humble shack. It is not overpowering or intimidating. But in institutional buildings, designed by architects who will never have to live in them, one is confined to a cell on some long and barren corridor, trapped among steam pipes amidst the roar from ventilating fans, and one dare not bore a hole in the desk lest this be considered sabotage. One may have the room remodeled perhaps, but he can be sure that this will be "properly" done, according to the dictates of Buildings and Grounds. Altogether, the feeling is that one is just passing through and doesn't belong; but in the home lab everything is a reflection of one's own personal needs and tastes.

How does one manage in more simple and buccolic surroundings? Doubtless one must like to work alone and this regimen is not to be recommended to those who need the social support of others doing the same work around them in order to keep going. Yet a compensating advantage, it seems to me, is the fact that in such an isolated situation one has to face problems unreservedly. Only the substantial yield counts, for there is no one to see or to care that you are "busy." Coming up with something is the only self-justification available. So on this score let me say that in one year the motivation problem disappeared and since then there has been no difficulty in keeping steadily at work every day. Moreover, there is the special advantage for continued observations that I can easily look at my experimental animals before retiring or during the night, as sometimes becomes necessary, without inconvenience.

My work is currently supported by the Cancer Research division of the National Institutes of Health. Although I do not work on pathological material it is hoped that fundamental studies on cell differentiation such as I am doing will contribute to our understanding of the cause and cure of abnormal growth. Since the frontal attack has so far failed, it is possible that some flanking approach may yield the insight that is needed. So far it has been possible to demonstrate that many epigenetic principles, like organ fields, determination of anlagen, induction, and specific inhibition of differentiation have their parallels in the unicellular material which may therefore provide a fresh approach to an analysis of the intimate basis of these phenomena. And recently it was discovered that crowded, unfed stentors of certain races do in fact give rise to "cancerous" forms in which the usually exquisite and remarkably reconstitutive organization goes wild and produces grossly abnormal shapes which are doomed.

If there is a moral to this account of my experience in lone research it is, I suppose, first that it should never be forgotten that in spite of all the aid that institutions may give it is only in individual minds that discoveries are made, and second that emergence of new trends and fashions in research or other matters does not mean that older means and arrangements are no longer possible or desirable. While missles are circling the moon it may still be possible to discover enough space in a place of one's own alone.

Dr. Vance Tartar is Research Assistant Professor of Zoology at the University of Washington and resides at Oysterville, Washington.

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CAREERS IN BIOLOGY: WILDLIFE MANAGEMENT

Wildlife management is a professional field concerned with production and use of game and fur animals and other wildlife. Management of wildlife is an important aspect of land management, and experts are needed by government and private industry.

Wildlife management is the science and technology devoted to the production, regulation and utilization of game, fur animals and other wildlife. It is a relatively young field which has developed rapidly since 1930. The management of animals is an important part of land management, and requires a thorough knowledge of what they eat, how they reproduce, where they find shelter, and how they affect timber, agricultural crops and one another. The maintenance of habitats favorable to survival of wildlife and to furnish recreation of many kinds is one of the chief responsibilities of the wildlife manager. This requires trained wildlife scientists, including technologists, research workers, administrators, teachers and public relations personnel. Success of a worker depends upon his interest in animals and the out-of-doors, his aptitude for working with people, and his training.

Recognition of the need for technical knowledge about wildlife has opened unusual opportunities for college graduates in this field. Opportunities for employment are numerous and varied. Graduates are employed by such governmental agencies as the U. S. Fish and Wildlife Service, the U. S. Forest Service, the National Park Service and other federal units. State departments of conservation have many openings for young men in wildlife research, administration and management. New developments in the field of employment are with private land owners, hunting clubs, operators of forest properties and other wild lands in producing and harvesting wildlife crops.

CAN GENERAL BIOLOGICAL SCIENCE COURSES BE TAUGHT SCIENTIFICALLY?

John Thornton

One would think that a science course would be taught scientifically, but I find that this is often not the case. In many text books used in such courses, there is a page or two on the scientific method. The instructor often spends part of a lecture explaining that persons doing scientific research establish "fact" by a method which involves stating the problem, proposing a tentative solution, gathering all available evidence which seems to bear on the problem, performing experiments, if possible, which test the solution, and finally judging the correctness of the original tentative solution on the basis of the gathered information. The instructor usually points out that it is poor practice to rely on the testimony of authorities when seeking to prove a scientific argument.

After explaining the scientific method, many instructors then try to "cover the field" of biological knowledge in an elementary manner, giving the student an annotated outline of the field of biology upon which he may later build by adding more specialized courses. The task of "covering the field" is a large one and gets larger each year. There is obviously insufficient time to establish the basis for each generality. Many courses thus consist of a series of general statements, temporarily remembered by the students, to be returned to the instructor on examination day. Often these courses are supplemented by a text which is little more than a collection of more general statements. What is actually happening in these courses is that the students are asked to believe a series of statements about biology upon the authority of the instructor or of the text. The majority of general courses with which the writer has had contact are of this nature.

I suggest that students given this type of course are led to believe that biology is a great mass of rather complex and often uninteresting information. They must feel that their instructors are a little hypocritical to say that knowledge develops in one way and to act as though it develops quite differently.

Would not students be more likely to think scientifically if their first acquaintance with a science was one in which they saw that the scientific method was indeed a useful method for solving problems? One approach which might be used would be for the instructor to point out that certain basic problems exist in biology and that biologists have directed their attention to these problems. Students are probably already aware of such problems and have no doubt asked themselves such questions as "How are characters transmitted from parent to offspring?" "How do animals and plants develop from a single cell?"

"How do the various parts of our body function?" and other such biological questions. The instructor might point out that such problems as these are made up of smaller and more specific problems. If we are to make any decisions about such matters, we must first state our problem precisely, then suggest possible solutions, and finally consider all the evidence on the problem which we can find. It will soon become evident that because of the size of the task, one is forced to consider only a relatively small portion of the biological field and must resort to authority in other areas until more time is available. The instructor would then direct the students in examining carefully the evidence bearing on certain key problems in biology, placing particular stress on those areas in which he himself is well trained. If a survey of the entire biological field is desired, a general text can be used for this purpose, but the lecture and laboratory should be used for a scientific investigation into some few individual biological problems.

Perhaps such a course would lead to an appreciation of the tremendous quantity of experimental facts which make up biology. It should also make the students aware of a method of solving problems. We hope that it would point out that scientific generalities are not truths to be written upon your heart but only statements of our present understanding of basic problems, important elements of which are still unsolved.

Some point out that such an approach will not work in general courses, because students prefer to have conclusions made for them and summarized in neat outline form. If an instructor points out that the evidence is conflicting on a certain point, the students may take the attitude that the instructor is not properly prepared, because obviously a thing is either so or it is not so! Some point out that the scientific method is the proper method for establishing truth but cannot be applied to the teaching of subject matter where methods of persuasion must be used. The most common objection raised against such a method is that one cannot cover all the material which must be covered in a general course by use of this method.

Such objections may be countered to the suggestion that, since any student retains very little from any one course, it is important that the most important things be emphasized so that what students do retain will be of significance. I believe that the scientific way of solving problems is what should be emphasized and that this can best be done in teaching by applying this method to a few individual problems.

John Thornton is an active member of Psi Chapter, University of Washington.

THE EDITOR SPEAKS

Recently, in the course of the prosecution of his research, the editor had occasion to refer to a memoir the authors of which are continually getting lost in wonder at the ignorance and obtuseness of nearly all their predecessors! By inference, *we* are asked to marvel at the perfect state of knowledge of these present authors. What has been missed — and this is the subject of the present paragraphs — is the relativity of all scientific work.

It is a part of our faith that the scientific method is one of the great discoveries of the human mind. But, however confident we are of the overall efficacy of the scientific method, we must remember that it is being operated by ordinary human beings. It is to lose perspective to view our predecessors either as supermen or as stupid pretenders or as other than imperfect bias-beridden error-prone seekers after better knowledge like ourselves. Our and their limitations and mistakes and errors are evidence that knowledge is difficult and laborious to come by. And, perhaps, some of the formulations that we so carefully and precisely make today will appear little better to our successors than do some of the formulations of our predecessors appear to us.

Humility is a virtue that the scientist must always practice — humility in the presence of the wonder of nature and the power of the scientific method — humility before the imperfect humanity of himself and his fellow scientists.

* * *

Psi Chapter has experimented with a novel method for arousing interest in Phi Sigma on the part of prospective members. Such persons are first invited to an open meeting, at which the nature of the society and its activities are explained. The result is that when these persons are later invited to become members, they know what it is they are being approached to join. In the past it has been the chapter's experience that, on a large campus like the University of Washington's, many persons when invited to join have never heard of the organization before. At any rate, the chapter has had an unusual number of acceptances as a result of this plan. Perhaps other chapters on large campus will find it advantageous to consider such a procedure.

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There is one thing about the present issue of the Biologist that the editor hopes will disturb the reader as much as it does him, and that is the extent at which it has been produced at the University of Washington!

This situation can be remedied in the future only if the general membership submits contributions to the editor! On the other hand, the editor is happy to point out that two of the articles are by presently active members of Psi Chapter. He hopes that this will induce active members of other chapters to offer similar contributions.

Alpha Omicron Chapter

Just as we go to press a five page Alpha Omicron Chapter (Marquette University) Newsletter (vol. 4, No. 1) comes to hand. The Chapter seems healthily active. Chief institutional news is that Marquette is freeing itself from that eighteenth century anachronism of separate botany and zoology departments and is instituting a single Department of Biology. Congratulations!

Book Notice

Obligatory and Facultative Insects in Rose Hips: their Recognition and Bionomics. By W. V. Balduf. Illinois Biological Monographs No. 26. Univ. of Illinois Press, Urbana, 1959, 194 pp., 12 plates.

This is a detailed biological study of some thirty species, mostly holometabolous insects, that comprise a microcommunity centering in the rose hip. The author's main attention is directed to six phytophagous species (3 Trypetid Diptera, an Olethreutid moth, the rose curculio, and a rose seed chalcid) and their associated Hymenopterous parasites and a few species of predators. He ranges freely over the literature, however, as the 250 odd titles in his bibliography show, and in one instance lists 30 species of hosts known to harbor *Bracon mellitor* Say, one of the parasites of the rose curculio. The plates contain 53 beautiful figures, and the whole is sumptuously bound in red cloth.

BOOK NOTICES

The Genetical Theory of Natural Selection. By Ronald A. Fisher. 2nd revised edition. Dover Publications, New York, 1958, 291 pp., illustrated. $1.85.

The importance of this book is its demonstration of the inevitability of natural selection in all situations in which the organism may be placed. In fact, the firm recognition in the present century of natural selection as nearly the only possible mechanism of evolutionary change may well date from the appearance of the first edition of this work in 1929. Though parts are highly mathematical, the "plain English" parts are such as to warrant the attention of the most "non-mathematical" biologist. The concluding chapters on the role of inherited sterility in human history suggest that "culture" may be the result rather than the cause of such sterility, which is to say that small families have made for increased cultural achievement on the part of their members rather than visa versa.

Time, Life, and Man: The Fossil Record. By R. A. Stirton. John Wiley & Sons, New York. 1959. 558 pp., 291 figs. $9.

This comprehensive book by the professor of paleontology and director of the Museum of Paleontology at the University of California is a unique attempt to provide a text for a course in introductory paleontology and a reference for the general reader. After an initial 145 pages on general principles and methods, the author devotes 210 pages to an account of the plants and animals existing during each of the great geological periods. A concluding series of 8 chapters treats of such topics as foraminiferology — the term is the author's (p. 376), cephalopods, the evolution of plants, vertebrates, dinosours, birds, horses, Primates, and man. Insects are only scantly considered. The text, in addition to an introductory chapter on the history of paleontology, is interestingly bestrewn with anecdotes from the lives and adventures of the paleontologists of the past.

The reviewer's chief criticism concerns the somewhat over liberal reference to generic names. So far as the reviewer is concerned, a generic name is just an odd combination of letters until it is made concrete by a verbal definition or a figure. The figures in this text are many and good, but too frequently generic names stand alone, a significant reminder to the specialist but hardly an aid to the uninitiated.

An important function of such a book is as "refresher" for those unfamiliar with the recent paleontological literature. Stirton thus refers (p. 90) to the first evidence of living things in Archeozoic rocks 2.6 billion years old, the probable existence of land plants in the earliest Paleozoic or even the Pre-Cambrian (p. 388), the records of flowering plants in the Triassic and Jurassic together with the probability that they existed in the Permian (pp. 289, 398), the first fossil vertebrates in the Ordovician (p. 406), and the lack of evidence for teeth in the jaws of *Hesperornis* (p. 453). The reviewer was incredulous to read (p. 226) that nearly 500 kinds of dragonflies have been described from the Pennsylvanian!

Fundamentals of Ecology. By Eugene P. Odum in collaboration with Howard T. Odum. Second Edition. Saunders, Philadelphia. 1959. 546 pp., 158 figs., 32 tables.

A comprehensive documented introduction to ecology, consisting (pp. 1-287) of a statement of general principles with many concrete examples, a review (pp. 287-418) of the principal biological habitats, and a concluding section (pp. 419-496) on applied ecology. Here such topics as the control of natural resources, public health, human ecology, and the new topic of radiation ecology are considered. The author is professor of zoology at the University of Georgia. This is a very fine book, but the text is in error on p. 414 in attributing only a few hundred species of insects to all of France. French beetles alone number over 8000 species, and the beetle fauna of the British Isles constitutes less than 20% of the total insect fauna of those islands.

Environmental Conservation. By Raymond F. Dasmann. John Wiley & Sons, New York, 1959. 307 pp., 153 figs. $6.50.

A systematic ecologically and historically founded survey of the conservation problem with attention to both its economic and aesthetic-cultural implications.

A Guide to the History of Bacteriology. By Thomas H. Grainger, Jr. Ronald Press, New York. 210 pp. 1958. $4.50.

A classified indexed bibliography of 2802 references, the last 783 of which are biographical notices of 60 alphabetically arranged microbiologists.

Chemical Transformations by Microorganisms. By F. H. Stodola. John Wiley & Sons, Inc., New York, 134 pp., portrait. $4.75.

Three lectures given by the author at the Institute of Microbiology, Rutgers University have been published as a short book. The book contains brief discussions of a rather large number of unrelated subjects and, except for the first chapter, microbial reactions of industrial importance are emphasized. The first chapter reviews the chemical anatomy of bacteria, including considerable information on the lipids, proteins, and polysaccharides found in *Mycobacterium tuberculosis*. The second and third chapters outline some of the degradative and synthetic reactions carried out by microorganisms. An extensive list of microbial oxidations of steroids has been included and other degradative reactions are enumerated with one or two examples. Several synthetic reactions (pigment production, penicillin synthesis, and the production of alpha ketoglutaric acid and glutamic acid) are discussed in greater detail. There is a fairly thorough, but concise, presentation of transglycosylation reactions, with numerous examples; the mechanisms of the reactions and the identification of oligosaccharides formed in these reactions are outlined. There is also a good summary of the history and present knowledge of the gibberellins. This book may be recommended chiefly for its brief outline of microbial reactions of industrial importance and for its presentation of some of the problems encountered in industrial fermentations. — Helen R. Whiteley.

Viral and Rickettsial Infections of Man. Edited by Thomas M. Rivers, M. D. and Frank L. Horsfall, Jr., M. D. Third Edition. J. P. Lippincott Co., Philadelphia. 1959. 967 pp., 134 figs. $8.50.

The purpose of this book is "to provide comprehensive information relative to viral and rickettsial infections which meets the needs of graduate students of biology, including those who are preparing for a career in medicine." The editors have enlisted 42 contributors, thus making it possible to have first-hand information on all of the various subjects covered.

Of particular interest to the biology student are the introductory chapters which give up-to-date coverage of discoveries and ideas concerning the nature of viruses and rickettsii, their methods of reproduction, their host cell relationships, etc. There is also some material on modern culture techniques and study methods.

Thirty-five of the 46 chapters deal with the human-infecting viruses and rickettsii. Several new chapters having been added in this new edition. The low price has been made possible by a grant from the National Foundation. It is a work to which all students of biology should have access. — David V. McCorkle.

Nomenclature of Plants. A text for the application by the case method of the International Code of Botanical Nomenclature. By Harold St. John. Ronald Press, New York, 157 pp., 1958. $2.50. The basic bibliography for the study of 958 "cases."

Algae. The Grass of Many Waters. Second Edition. By Lewis Hanford Tiffany. Charles C. Thomas, Springfield. 1958. 199 pp., 41 plates, 13 figures. $6.50.

This book is a general introduction to the algae for the non-specialist. It tells what algae are and how they feed and grow and reproduce. The algae of lakes, ponds, streams, rivers, the sea, the soil, ice, snow, and of various symbiotic and parasitic habits are passed in review. The geological history and economic importance of algae are surveyed, and brief directions for their collection and study, including a short basic bibliography are given. Two hundred or more genera are illustrated on the many plates. An excellent book for the beginner or for the high school biology library.

Comparative Morphology of Vascular Plants. By Adriance S. Foster and Ernest M. Gifford, Jr., W. H. Freeman and Co., San Francisco, 1959, 555 pp., illustrated. $9.00.

After a generalized introduction, the authors consider the anatomy of the major phyla of Tracheophyta with reference to their comparative morphology, fossil history, and phylogeny. Separate chapters are devoted to the Psilopsida, the Lycopsida, and the Sphenopsida. Four chapters treat of the Pteropsida, four chapters of the Gymnosperms, and two chapters of the Angiosperms.

Spring Flowers of the Lower Columbia Valley. By Clara Chapman Hill. With 71 full page drawings and 22 other figures by Mary Comber Miles. Univ. of Wash. Press, Seattle. 164 pp., 1958. $3.00.

Keys and descriptions of nearly 300 species of herbs and shrubs adapted for the use of beginners.

Tree Maintenance. By P. P. Pirone. Oxford Univ. Press, New York, 483 pp., 147 figs. 1959. $10.

This attractive book is a manual on the maintenance of shade and ornamental trees. The author, who is a well known horticulturalist, is plant pathologist in the New York Botanical Garden. His book will appeal primarily to persons professionally engaged in arboriculture, but the extensive section (pp. 200-428) on the diseases and insect pests of trees will be of interest likewise to plant pathologists and entomologists and the book as a whole will appeal to horticulturalists.

Annual Review of Entomology. Vol. 4. Edited by Edward A. Steinhaus and Ray F. Smith. Annual Reviews, Inc., Palo Alto. 1959. 467 pp. $7.

A collection of 19 essays (7 by Californians) skillfully selected to appeal in part to nearly every sort of entomologist. Physiology, taxonomy, biology, ecology, behavior, the insect, microbial, and chemical control of insects, the insect control of weeds, and agricultural and medical entomology are all represented and specialists on each of the half dozen major insect groups will all find plenty of pertinent material.

The Vertebrate Story. By Alfred Sherwood Romer. Univ. of Chicago Press, Chicago, 1959, 437 pp., illustrated. $7.00.

A revised edition of *Man and the Vertebrates*. The section on the human body — a third of the original work — has been omitted, and the account of the lower vertebrates greatly expanded. The same fine type of plates as before, but this time on the same kind of paper as the text.

Studies on the Structure and Development of Vertebrates. By Edwin S. Goodrich. Paperback, 2 volumes. lxix + 837 pages, 754 figures. Dover Publications Inc., New York, 1958. $5; the two volumes ($2.50 each).

Students of the vertebrates need no introduction to this book, which has been called the "opus magnum" of one of the greatest of zoologists. Since its original publication it has stood as a standard reference in the field of vertebrate anatomy, embryology and evolution, a position which it still holds after nearly thirty years. Although not all of the systems are covered, the skeletal, vascular, respiratory, urogenital, and nervous systems and the body cavities are very thoroughly discussed.

Dover has done the zoology student a real service by making this valuable work available in inexpensive paperbacks, handily divided into two volumes. The large number of illustrations, many by Goodrich himself, add greatly to the utility of the book. A special feature is the inclusion of a reprint of the extremely interesting obituary and review of the work of E. S. Goodrich by A. C. Hardy, which first appeared in the Quarterly Journal of Microscopical Science in 1946, including a complete list of Goodrich's publications. — David Miller.

William Harvey's *De Motu Locali Animalium 1627*. Edited, translated, and introduced by Gweneth Whitteridge, Cambridge Univ. Press, New York, 163 pp., frontispiece. 1959. $10.50.

This fine book is an elaborately annotated chapter in the life of the first important experimental biologist. Harvey's Latin notes "Of Local Movement in Animals" were for a book he never finished. Now edited and translated, they give us an important insight into the *modus operandi* of this top notch seventeenth century scientist.

Reproductive Physiology. By A. V. Nalbandov. W. H. Freeman & Co., San Francisco, 1958. 271 pp., 38 figures, 56 tables. $6.75.

This book brings together in readable interesting form information which is generally ignored or hastily covered in descriptive elementary courses in embryology and physiology. Some of the topics covered are: the biology of sex (sex determination mechanisms); the structure of male and female reproductive systems; the endocrinology of reproduction (reproductive cycles); follicular growth, ovulation, formation of corpora lutea; chemical and physiological effects of hormones; reproduction in male mammals and birds; the young embryo; fertility and sterility. — David Miller.

Virginity, Pre-nuptual Rites and Rituals. By Dr. Ottokar Nemecek. Philosophical Library, Inc., New York, 129 pages, 16 plates. $4.75.

This book contains both anthropological and philosophical discussion of the subject of sexual morality. In the first three chapters, which are largely anthropological, Dr. Nemecek traces the causal relationship between the socio-economic framework in which various groups live and their outlook on life, with its accompanying attitude toward virginity. The fourth and final chapter contains the real essence of the book, a discussion of the philosophy of sexual morality. Dr. Nemecek claims that there is no such thing as an objective, scientific, or "true" morality; moral judgements are only of value within the particular frame of reference in which they are made. Moral values change with the surroundings and situation. Virginity itself is a vague and inexact thing; there are as many as seven different mental attitudes, or "reasons," which can lead to the same physical state. This is not however to be interpreted, says the author, as an excuse for immorality. The knowledge that morality is relative and judgements transitory in application "... does not diminish the responsibility of those motives within the environment in which they are effective..." — David Miller.

The Birth of Normal Babies. By Lyon P. Strean. Twayne Publishers, New York. 1958. 194 pp. $3.95.

This is an attempt to reduce the "10%" of pregnancies that end in miscarriages, still births, or malformations, by the education of the public. There is much repetition of facts and the contents could have been presented in a fairly short article. The book is misnamed and does not deal with "the birth of normal babies," but with the development of abnormal babies and its causes. A woman in the later stages of pregnancy, reading the book for the first time, would surely wonder and worry if she had violated any of "the 10 commandments of genesis." On the other hand, for a woman to read the book before pregnancy might be extremely beneficial. Dr. Strean feels that miscarriages, still births and congenital abnormalities are due to a multitude of causative factors which he discusses under the three categories of traumatic, physiological, and emotional stresses. The book is well written and easily read. — William L. Shapeero.

Readings in General Psychology. Edited by Paul Halmos and Alan Iliffe. Philosophical Library, New York, 1959, 251 pp. $6.00.

The Unconscious in History. By A. Bronson Feldman. Philosophical Library, New York, 1959, 269 pp. $4.75.

Group Psychoanalysis. By B. Bohdan Wassell. Philosophical Library, New York, 1959, 306 pp. $3.75.

Dorland's Pocket Medical Dictionary. 20th Ed. Saunders, Philadelphia, 1959.

The most recent edition of a dictionary first published in 1898.

Symposium on Information Theory in Biology. Edited by Hubert P. Yockey with the assistance of Robert L. Platzman and Henry Quastler. Pergamon Press, New York, 1958, 418 pp., illustrated. $12.00.

This is the report of a symposium at Gathinburg, Tennessee, October 29131, 1956, sponsored by the Oak Ridge National Laboratory and devoted to information theory in health physics and radiobiology. It consists of about 30 highly technical papers by about as many authors on various aspects of this field of mathematical biology and its applications.

The Atom and The Energy Revolution. By Norman Lansdell. Philosophical Library, Inc., New York. 200 pages, 32 plates. $6.

For several years the problem of diminishing resources for the production of power has been a pressing one, especially in Europe, and man has looked to the atom to provide the answer. In this book Mr. Lansdell tells what is being done and what is planned for the future to harness atomic energy for peacetime commercial and industrial uses. Mr. Lansdell is apparently not himself a scientist, but he shows a clear grasp of the general principles of atomic energy. He discusses the atom and its structure and shows how energy can be derived from it by either fission or fusion. Also discussed are the world position and that of various countries with respect to available conventional forms of energy, raw materials for atomic reaction, possible other new sources of power (such as solar heat), methods of releasing atomic energy, including the basic theory and construction of atomic reactors, political implications of atomic power, methods of utilization, the present development and future plans of several countries, international organizations bearing on atomic energy, and, of particular interest to biologists, the health risks created by atomic reactors and by the disposal of atomic waste. — David Miller.

The Chemical Analysis of Foods and Food Products. By Morris B. Jacobs, 3rd Ed., D. Van Nostrad, Princeton, 1958, 970 pp., 88 figures, 109 tables. $12.00.

A comprehensive manual of procedures employed in the routine chemical analysis of food and food products in the United States.

Surface Phenomena in Chemistry and Biology. Edited by J. F. Daniellie, K. G. A. Pankhurst, and A. C. Riddiford. Pergamon Press, New York, 1958, 330 pp., illustrated. $10.00. A series of 23 chapters by 26 different authors on this very basic subject.

Biological Laboratory *Data*, by L. J. Hale; John Wiley & Sons, Inc., New York, 1958, 132 pp. $2.75.

In 128 pages the author has packed a large number of what he considers the most useful charts, tables and data from the various fields that a worker might need to draw information pertinent to his research. The sections of the book are: mathematical data, weights and measures and inter-relations of units, statistical data, physical and chemical data, saline and culture media, and miscellaneous data (including such things as symbols for proof correcting and photographic data). As the author points out "the book contains a selection of data; it is not an encyclopaedia." In most cases no explanation of the charts are supplied — it is assumed that the reader knows the use of them. For those who wish to investigate the fields further a small select bibliography is supplied at the end of each section. It is my belief that most will find the book quite useful. — William L. Shapeero.

A History of Cytology. By Arthur Hughes. Abelard-Schuman, Ltd., London. 1959. 158 pp., 12 plates. $5.

Every person interested in general biology should find this book important and exciting reading. In it the author, who is University Lecturer in Anatomy at Cambridge University, sets forth the genesis of ideas like the cell theory, mitosis, gametogenesis, fertilization, the chromosome theory of heredity, and the structure of nucleus and cytoplasm, ideas with which we have been familiar since our earliest contacts with biology. Here we read how those theories, now found in every elementary text, first came to be. The pattern that frequently emerges is one of scattered observations followed by hypothesis formation and argument and debate pro and con, ending finally in the generalizations which we know so well. Or a subject like the structure of cytoplasm is caught half-way through its act, with nineteenth century generalizations now largely discarded and no even moderately satisfactory hypothesis yet in sight. The plates reproduce a series of historically important drawings.

Throughout, the author keeps reminding us that the growth of cytology has depended heavily on the development of optical instruments and adequate staining and sectioning and experimental breeding techniques. Cytology's classical period was the last quarter of the last century with such Europeans as Oscar Hertwig, Hermann Fol, E. van Beneden, Eduard Strassburger, Walther Flemming, T. Boveri and others dominating the field. If the reviewer has any criticisms, they relate to the inadequately short bibliographical citations and to the lack of personal references. A fine addition would have been a series of biographical footnotes — or a biographical appendix — in which for each of the historically important persons, mention would be made of his full name, his dates, his important professional positions with their dates and, perhaps, a brief characterization of his importance. As it is a name like "W. Waldeyer," who introduced the term "chromosome" in 1888, stands in unattached isolation! The general purport of the book is, however, entirely commendable. Says the author, most potently (p. X): "A greater awareness of historical perspective... might help to dispel the illusion too often implicit in reports of fresh discoveries, that the final secrets are nearly within reach."

The Autobiography of Charles Darwin and Selected Letters. Edited by Francis Darwin. Dover Publications, New York, 1959, 365 pp., $1.65.

This is virtually a facsimile reprint of a book entitled *Charles Darwin. His Life Told in an Autobiographical Chapter and in a Selected Series of his Published Letters* that appeared in 1892. This publication in its turn was an abridgement of the three volume *Life and Letters* that had appeared in 1887. The book thus made currently available by Dover Publications is a selection by Darwin's son of original documents bearing on the life of the great evolutionist. It is thus the book to be read by one who would know more of Darwin than just what is told in the autobiography — 54 pages in the present edition — but who does not care to venture into the nine or ten volumes that otherwise document his life. The reader should remember, however, that the autogiography in the present volume is not the unexpurgated version edited by Nora Barlow last year, but the expurgations are of little importance to the general account. The book is illustrated by three delightfully familiar wood cuts: the house at Down and Darwin as an old man seated in a wicker chair as end papers, and the study at Down heading Chaper IV.

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THE BIOLOGIST

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MILE POSTS

1915 March 17, Alpha Chapter organized, Ohio State University, Columbus.
1916 May, Central Governing Body organized, "Biologist" first issued.
1924 December, First National Meeting, Constitution revised, Washington, D. C.
1925 December, Second National Meeting, Kansas City.
1926 December, Third National Meeting, Philadelphia.
1928 December, Fourth National Meeting, New York, Coat-of-arms adopted.
1930 January, Council Meeting, Ritual revised, Norman, Okla.
December, Fifth National Meeting, Cleveland.
1931 Phi Sigma Letters Registered, U. S. Patent Office.
1933 June, Sixth National Meeting, Chicago.
1935 December, Seventh National Meeting, St. Louis.
1937 December, Eighth National Meeting, Indianapolis.
1939 December, Ninth National Meeting, Silver Anniversary, Ohio State University, Columbus.
1941 December, Tenth National Meeting, Dallas, Texas.
1946 December, Eleventh National Meeting, Boston, Mass.
1948 December, Twelfth Meeting, Albuquerque, N. Mex.
1950 December, Thirteenth Meeting, Denver and Boulder, Colo.
1952 December, Fourteenth Meeting, St. Louis, Mo.
1954 September, Fifteenth Meeting, Gainesville, Fla.
1956 September, Sixteenth Meeting, Ann Arbor, Mich.
1958 September, Seventeenth Meeting, Albuquerque, N. Mex.

Phi Sigma is a Member of the Association of College Honor Societies, and Associate Member of both the A.A.A.S. and the A.I.B.S.

CHAPTERS FOUNDED

ALPHA — Ohio State University, Columbus, Ohio, 17 March 1915.

BETA — University of Michigan, Ann Arbor, Michigan, 3 June 1916.

GAMMA — North Dakota Agricultural College, Fargo, North Dakota (1916).

DELTA — University of Maine, Orono, Maine, 27 January 1917.

EPSILON — University of Denver, Denver, Colorado, 5 March 1917.

ZETA — University of Wisconsin, Madison, Wisconsin, 30 May 1917.

ETA — University of Akron, Akron, Ohio, 20 April 1921.

THETA — Michigan State College, Lansing, Michigan, 9 April 1921.

IOTA — Washington University, St. Louis, Missouri, 28 May 1921.

KAPPA — University of Kansas, Lawrence, Kansas, 31 May 1921.

LAMBDA — University of Montana, Missoula, Montana, 4 May 1921.

MU — University of California, Berkeley, California, 27 April 1922.

NU — Washington and Jefferson College, Washington, Pennsylvania, 11 May 1922.

XI — University of Nebraska, Lincoln, Nebraska, 3 May 1924.

OMICRON — University of North Dakota, Grand Forks, North Dakota, 26 May 1924.

PI — Emory University, Georgia, 3 January 1925.

RHO — University of Illinois, Urbana, Illinois, 28 March 1925.

SIGMA — University of Florida, Gainesville, Florida, 4 December 1925.

TAU — Duke University, Durham, North Carolina, 4 March 1926.

UPSILON — Miami University, Oxford, Ohio, 7 May 1926.

PHI — University of New Hampshire, Durham, New Hampshire, 21 May 1926.

CHI — Montana State College, Bozeman, Montana, 11 February 1927.

PSI — University of Washington, Seattle, Washington, 7 April 1928.

OMEGA — University of Oklahoma, Norman, Oklahoma, 24 March 1928.

ALPHA ALPHA — University of Southern California, Los Angeles, California, 17 May 1928.

ALPHA BETA — Mount Union College, Alliance, Ohio, 17 May 1928.

ALPHA GAMMA — University of South Dakota, Vermillion, South Dakota, 15 May 1928.

ALPHA DELTA — Lawrence College, Appleton, Wisconsin, 17 March 1929.

ALPHA EPSILON — University of Pittsburgh, Pittsburgh, Pennsylvania, 23 March 1929.

ALPHA ZETA — College of William and Mary, Williamsburg, Virginia, 19 April 1930.

ALPHA ETA — Oklahoma State University, Stillwater, Oklahoma, 13 March 1930.

ALPHA THETA — State College of Washington, Pullman, Washington, May 1930.

ALPHA IOTA — Bucknell University, Lewisburg, Pennsylvania, 9 January 1932.

ALPHA KAPPA — Hunter College, New York City, 8 January 1932.

ALPHA LAMBDA — University of Utah, Salt Lake City, Utah, 13 February 1932.

ALPHA MU — University and State College of Oregon, Eugene-Portland-Corvallis, Oregon, 18 November 1933.

ALPHA NU — University of New Mexico, Albuquerque, New Mexico, 21 April 1935.

ALPHA XI — University of Rhode Island, Kingston, Rhode Island, 17 May 1935.

ALPHA OMICRON — Marquette University, Milwaukee, Wisconsin, 18 June 1938.

ALPHA PI — University of Colorado, Boulder, Colorado, 24 May 1941.

ALPHA RHO — University of Arkansas, Fayetteville, Arkansas, 23 May 1945.

ALPHA SIGMA — University of Texas, Austin, Texas, 2 February 1946.

ALPHA TAU — National University of Mexico, Mexico, D.F., 7 April 1947.

ALPHA UPSILON — University of California at Los Angeles, California, 17 May 1947.

ALPHA PHI — College of Puget Sound, Tacoma, Washington, 28 February 1948.

ALPHA CHI — University of the Philippines, Manila, Luzon, P.I., 12 March 1949.

ALPHA PSI — Virginia Polytechnic Institute, Blacksburg, Virginia, 24 May 1949.

ALPHA OMEGA — University of Georgia, Athens, Georgia, 17 May 1951.

BETA ALPHA — Pennsylvania State Univ., State College, Pennsylvania, 26 May 1955.

BETA BETA — Florida State University, Tallahassee, Florida, 18 February 1956.

BETA GAMMA — Long Island University, Brooklyn, N. Y., 27 April 1957.

BETA DELTA — University of Virginia, Charlottsville, Virginia, 22 March 1958